

Deep Wide-field Space-based Imaging and Galactic Structure

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Wide-field surveys (POSSII, 2MASS, SDSS, SNAP, etc.) don't just image galaxies.

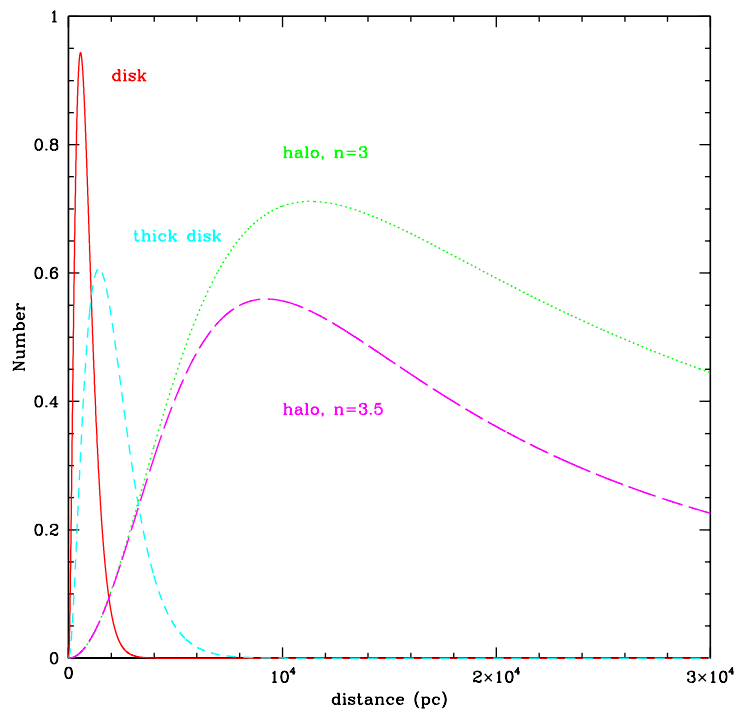
Starcount analyses probe the structure of our Galaxy
⇒ provide insight to galaxy formation

SNAP permits detailed study of the Galactic halo*, *in situ* at $Z > 5$ kpc.
⇒ first major epoch of star formation
Still the only halo where such detailed observations are possible.

* Galactic halo \equiv old, metal-poor *stellar* population

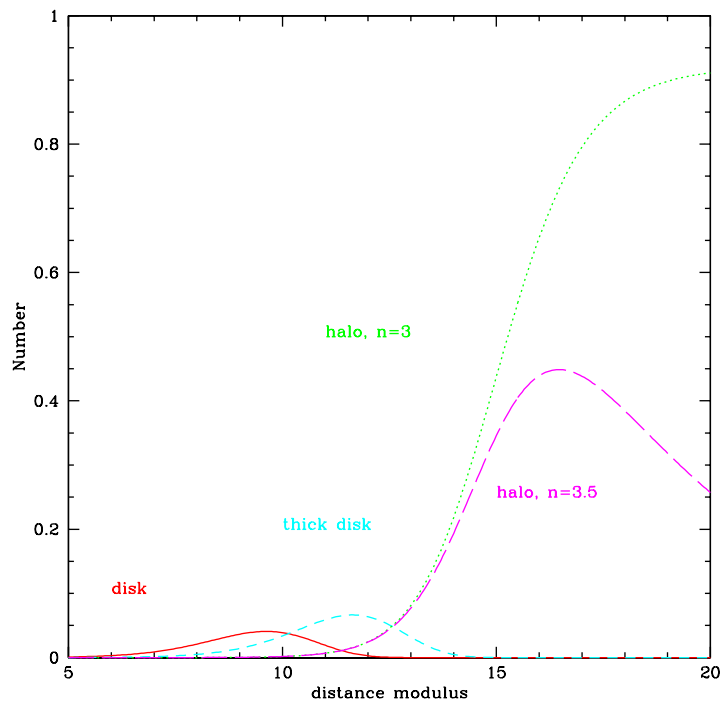
- Age: 12 to 14 Gyrs
- Mass: $\text{few} \times 10^9 M_{\odot}$
- Local number density: $\sim 1:200$ relative to disk
- Metallicity: < 0.1 solar
- Kinematics: Low rotation, high velocity dispersion
- Spatial distribution: near-spheroidal

Why is deep imaging necessary? 1

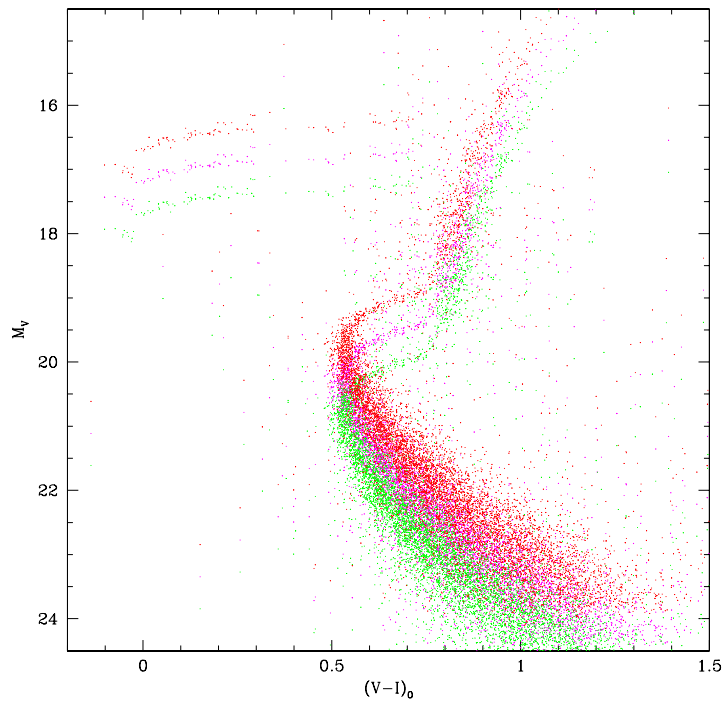


$$A(m) = \int \text{volume} \cdot \text{density}$$

$A(m)$ reaches maximum at approximately twice the effective scaleheight



Why is deep imaging necessary? 2

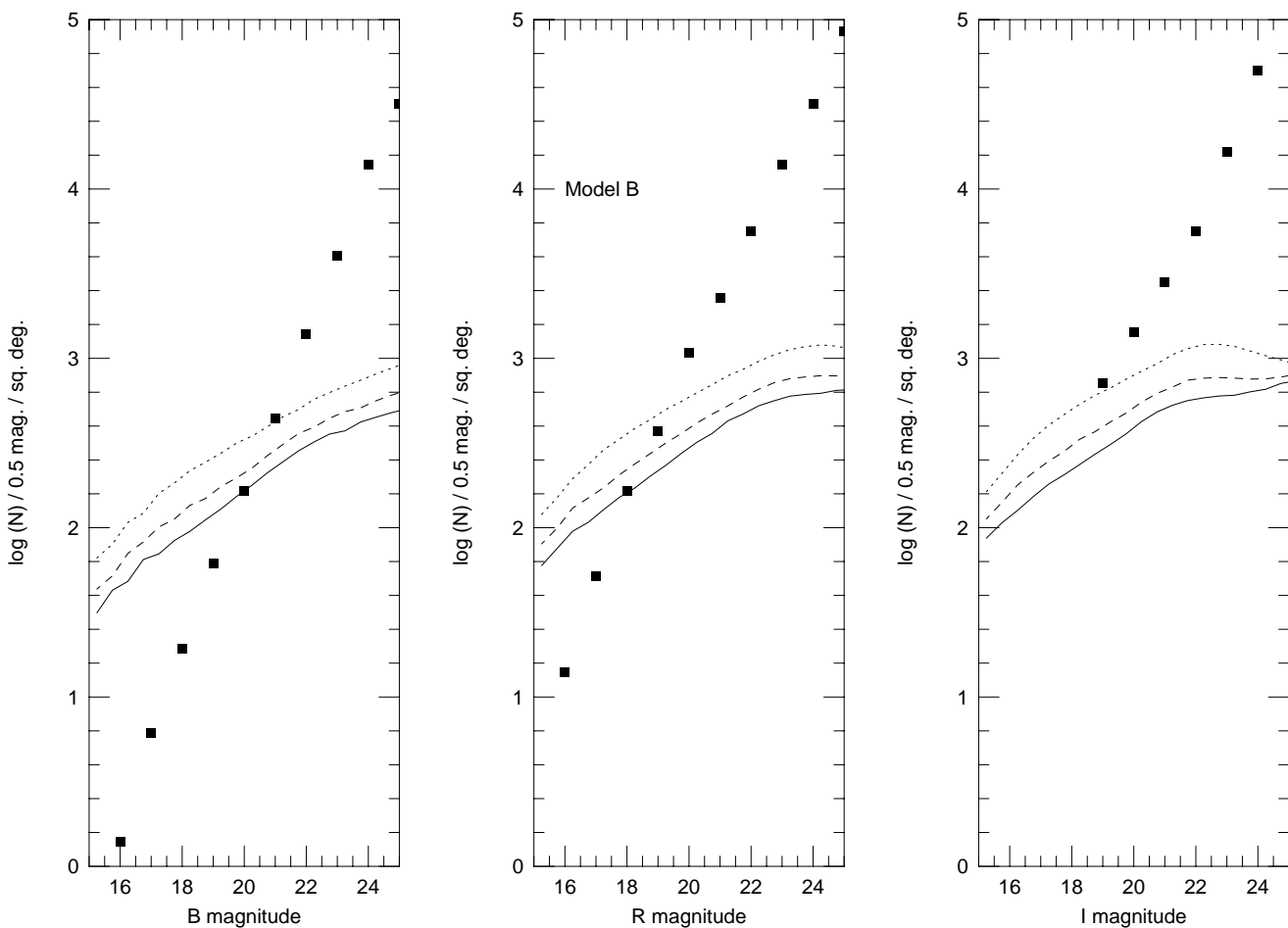


Starcount analysis relies on photometric distance estimators
Ground-based surveys probe magnitudes brighter than $V \sim 21$ to 22
 $\Rightarrow M_v < +5$ in the halo

- Red giants - steep CMD, poor distance estimator
- Subgiants - abundance sensitivity, poor distance estimator
- Turnoff stars - steep CMD, poor distance estimator
- HB stars - abundance sensitivity, moderate distance estimator

Need to go deeper to reach unevolved subdwarf main sequence.

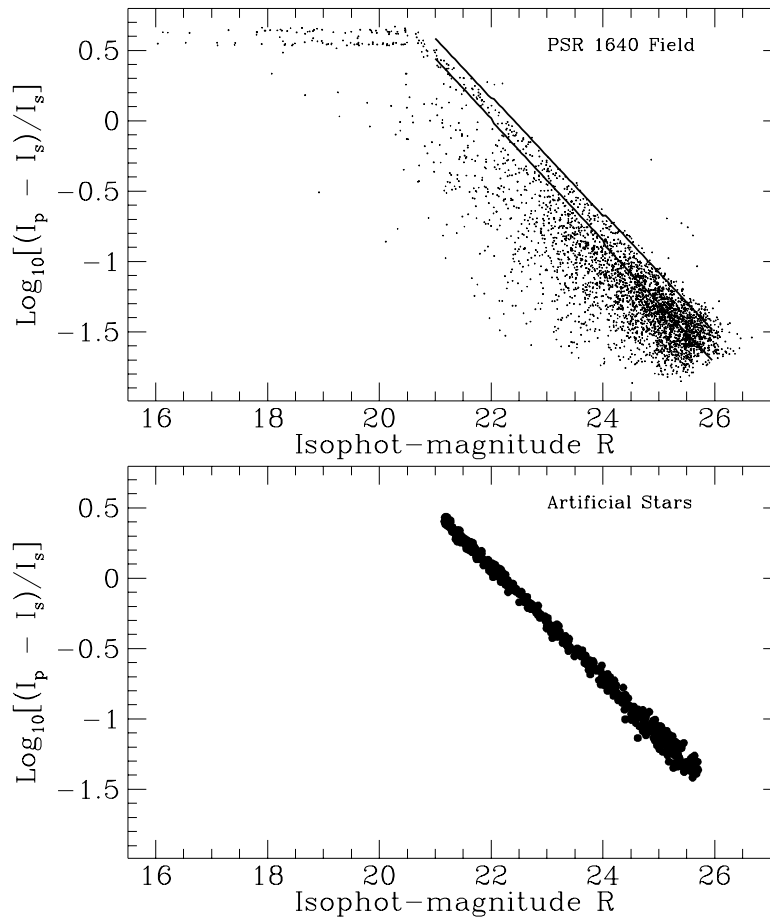
Why space-based imaging? 1



Galaxy counts vs. starcounts at $b=30, 60, 90^\circ$

- Galaxies dominate counts at faint magnitudes in high-latitude fields
outnumber stars by factors of 10 to 100 at $V > 21$
- Galactic structure analysis requires high accuracy star/galaxy separation techniques

Why space-based imaging? 2

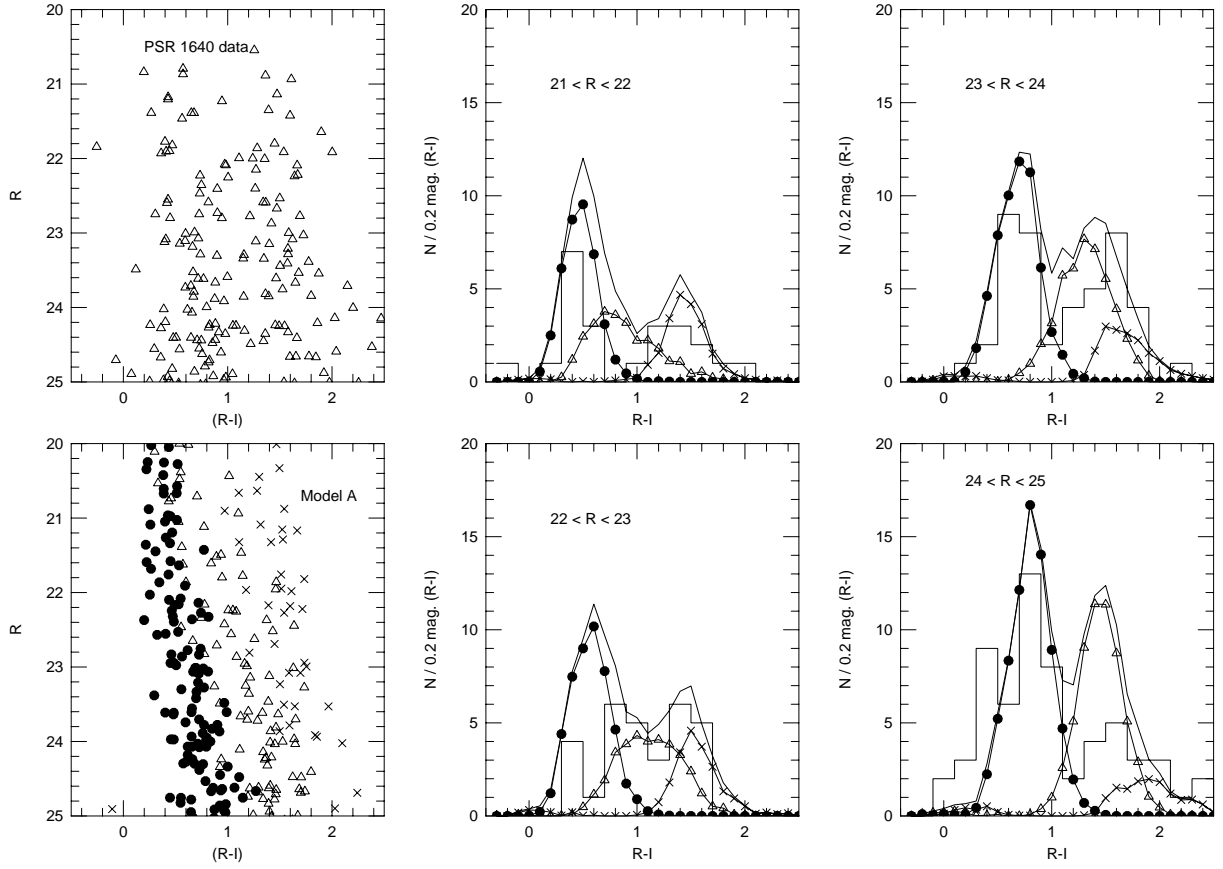


- Analysis of groundbased observations is limited by seeing
- Require large fields of view - so AO is little help
- Galaxies basically look like K stars - can't separate by colour
- Fainter than $R \sim 26.5/27$, a significant number of galaxies are expected to have dimensions of < 0.1 arcsecond
→ limit for purely morphological starcount studies
(use colour selection+proper motions?)
- Brighter than $R=26.5$, space-based observations provide a significant improvement over ground-based measurements

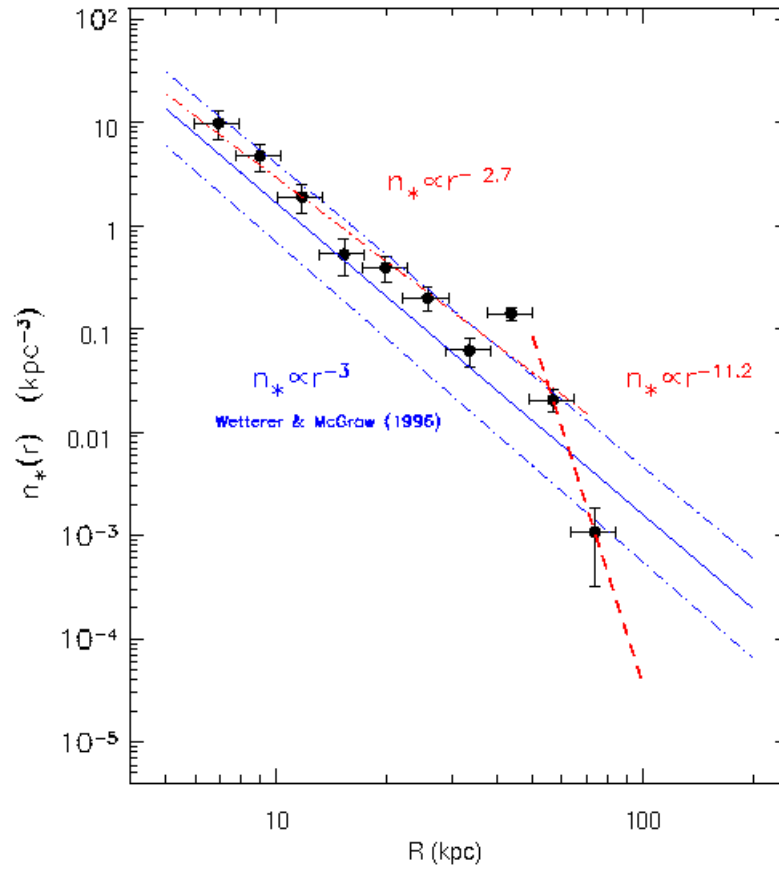
Expected stellar surface densities

R	N(star)	N(galaxy)	Stars/sq. deg.	$\langle M_R \rangle$
21.5	30	99	2570	5
22.5	33	208	2830	6
23.5	44	435	3770	7
24.5	75	911	6430	8

Based on Keck PSR1640 observations (Reid et al, AJ, 1996)



The density distribution in the halo



1. SDSS RR Lyrae data suggest halo truncation at ~ 40 kpc. (Ivezic *et al.*, 2000).
Do subdwarfs show the same effect?
2. Spatial sub-clustering: 1 sq. deg. $\equiv 30,000$ pc^2 at 10 kpc.
kinematic sub-structure (moving groups) is present in the halo (mergers?)
how uniform/well-mixed are halo field stars

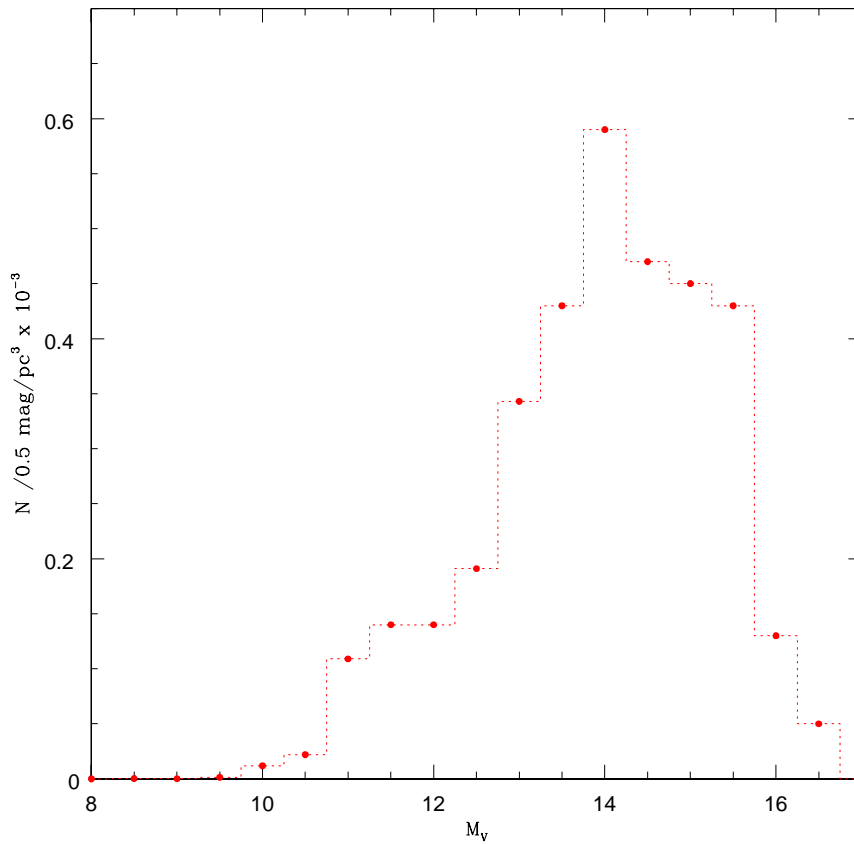
Proper motions at moderate→large distances above the Plane

$\mu = \frac{V_T}{4.74r}''yr^{-1}$, for V_T in kms^{-1} , r in pc.

So $\mu = 1 \text{ mas yr}^{-1}$ for $V_T=25 \text{ kms}^{-1}$ at 5 kpc.

⇒ can examine kinematics (dispersion, rotation, moving groups) for $1 < Z < 7 \text{ kpc}$.
i.e. disk/halo transition region

What about cool white dwarfs?



Data from Liebert *et al.* (1988) as updated by Mendez & Ruiz (2001).

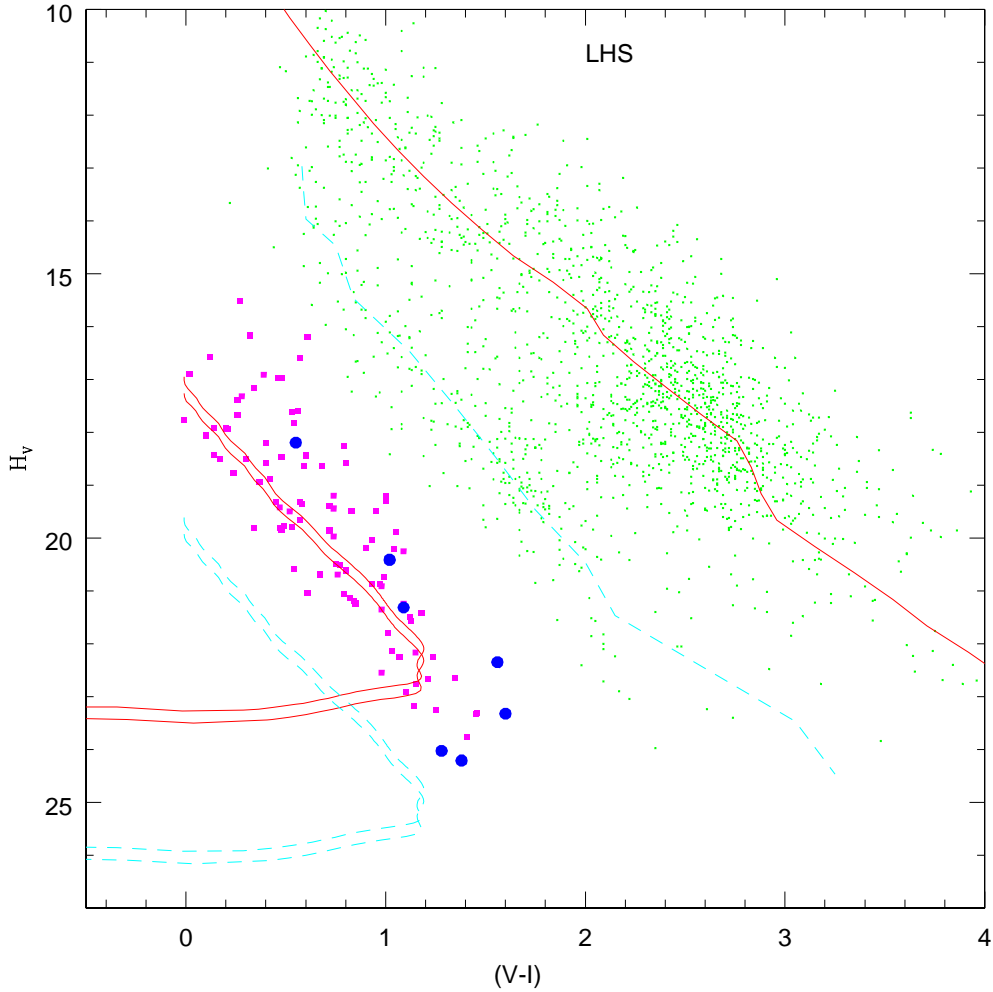
Cutoff in $\Phi(M_V)$ can probe the age of thick disk/halo, although.....

Halo → expect cutoff at $M_V \sim 17.5$

fully sampled only at $V \sim 34$!

What about dark matter (Oppenheimer et al, Nelson et al)

→ almost certainly irrelevant



$$H_v = V + 5 + 5 \log \mu = M_v + 5 \log V_T - 3.37$$

$(H_V, (V-I))$ sequence traces $(M_V, (V-I))$ sequence, offset by an amount dependent on the mean kinematics of the underlying population:

disk $\sim 80 \text{ kms}^{-1}$; halo $\sim 275 \text{ kms}^{-1}$ for Groth strip

Groth strip white dwarfs match low-velocity white dwarfs (i.e. disk)

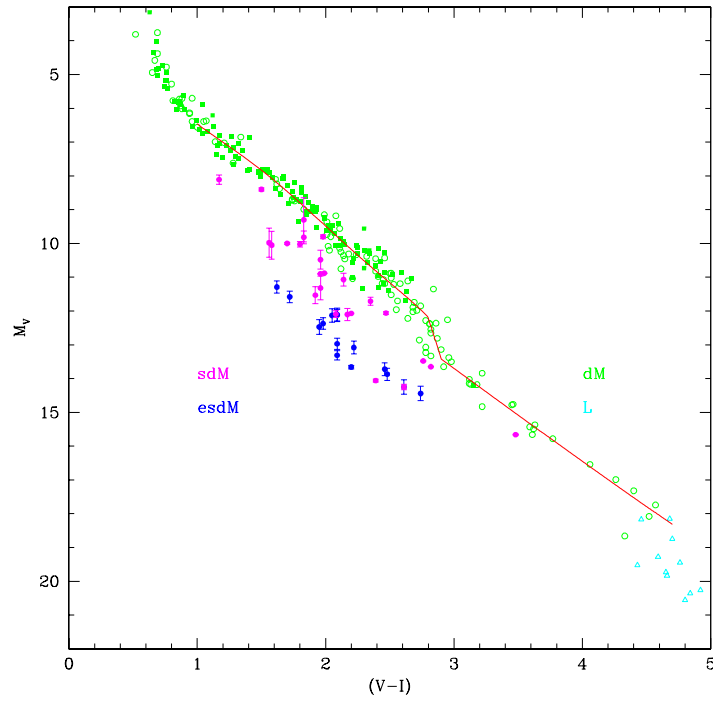
not classical, non-rotating dark matter

If they're dark matter,

1. Why do they match the younger cooling branch?
2. Why is the dark matter halo rotating?
3. Why is the (near-contemporary) stellar halo not rotating?

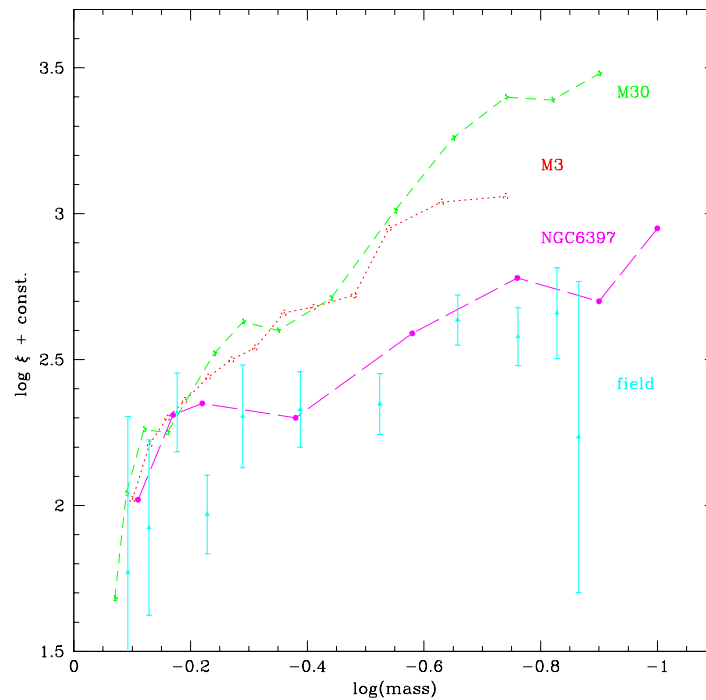
Evidence of inconsistency with model A \neq evidence in favour of model B

The halo subdwarf luminosity function



For extreme halo stars ($[M/H] < -1.5$), H-burning limit falls at $M_V \sim 15$
 \rightarrow limited sampling volume

Is $\Psi(M)$ flatter in the field than in most globular clusters?



Science issues: summary

1. Halo density law - from counts at faint magnitudes
is there an edge to the halo?
Spatial sub-clustering - how well-mixed is the halo?
Vertical density distribution for very late-type disk dwarfs.
2. Proper motions for faint halo stars
→ kinematics in thick disk/halo at $Z > 1.5$ kpc.
3. Probe halo luminosity function at faint absolute magnitudes *in situ*
4. Repeat observations should allow identification of faint variable stars (statistics on flares in low-mass halo subdwarfs?), contact binaries and, in particular, eclipsing binary systems ⇒ potential mass measurements (if the candidates are accessible to spectroscopy)

Limitations

1. Limited coverage in (l, b) ⇒ limited sensitivity to certain structural parameters
2. Star/galaxy separation requires well understood psf as f(position)
3. Even relative astrometry requires stable psf as f(position)

Deep starcount studies demand stable, reliable, well-calibrated images
→ but so does the supernova project....